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DECLARATION

I, Takeshi MIZUNUMA, a citizen of Japan, 1-20-16, Higashi-ohnuma Sagamihara-shi, Kanagawa Japan, do hereby sincerely declare:

(1) That I am well acquainted with the Japanese Language and English Language, and

(2) That the attached is a full, true and faithful translation into the English language made by me of the certification of the Japanese Patent Application No. 2002-242861 filed on August 23, 2002.

This January 27th , 2005 at Kanagawa, Japan

Takeshi Mizunuma

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[Title of the Invention] Rolling Bearing, Alternator and Transmission

[Claims] 3

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[Item]	Specification	1
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[Item]	Abstract	1

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[Name of Document] Specification (2002-242861)

[Title of the Invention] Rolling Bearing, Alternator and Transmission

[Scope of The Patent Claim]

[Claim 1] A rolling bearing comprising: an inner ring formed with an inner ring raceway on an outer peripheral surface; an outer ring formed with an outer ring raceway on an inner peripheral surface; and a plurality of rolling elements rotatably provided between the inner ring raceway and the outer ring raceway, characterized in that, when an outer diameter of the outer ring is D, a width of the outer ring in the axial direction is W, a minimum thickness of a part where the outer ring raceway is provided on a middle portion in the axial direction of the outer ring is h, and a diameter of each rolling element is Da, the relationship $1.20 \leqq \{(h^{1.5} \times W) / (Da^{1.1} \times D^{0.5})\} \leqq 2.00$ is satisfied.

[Claim 2] An alternator for rotatably supporting rotating members on an housing by a rolling bearing, wherein the rolling bearing is configured as recited in claim 1.

[Claim 3] A transmissions for rotatably supporting rotating members on an housing by a rolling bearing, wherein the rolling bearing is configured as recited in claim 1.

[Detailed Description of the Invention]

[0001]

[Technical Field to Which the Invention Belongs]

The present invention relates to ensuring durability of rolling bearings for rotatably supporting rotating members of various rotating machinery and equipment such as pulleys on automobile alternators and belt-type continuously variable transmissions, and gears and the like constituting manual transmissions and automatic transmissions. Particularly, in accordance with the rolling bearing of the present invention, even if it is fixed to a low-rigidity housing made of light metal such as aluminum alloy, premature flaking can be prevented in the rolling contact parts between the rolling contact surfaces of the balls and the inner ring raceway and the outer ring raceway.

[0002]

[Prior Art]

In various auxiliary equipment having as a power

source the drive engine of an automobile, a rotating shaft is rotatably supported in relation to the housing, and a driven pulley is fixed to one end of this rotating shaft on a portion projecting from the housing. The various auxiliary equipment can be freely driven by transmitting the rotation of the engine crankshaft to this driven pulley via an endless belt. FIG. 5 shows an example of an alternator which generates electric power necessary for an automobile, being one of such various auxiliary equipment. In this alternator 1 a rotating shaft 3 is rotatably supported inside a housing 2 made from a light metal such as aluminum alloy, by a pair of rolling bearings 4, 4. Each of these rolling bearings 4, 4 comprises an inner ring 6 having an inner ring raceway 5 formed on an outer peripheral surface, an outer ring 8 having an outer ring raceway 7 formed on an inner peripheral surface, and a plurality of balls 9, 9 being rolling elements, rotatably arranged between the inner ring raceway 5 and the outer ring raceway 7.

[0003]

Moreover, a rotor 10 and a commutator 11 are provided in the middle portion of the rotating shaft 3. Furthermore, a driven pulley 12 is fixed to an end part of the rotating shaft 3 projecting from the housing 2. With the housing 2 fixed to the engine (not shown in drawings), an endless belt (not shown in drawings) is wrapped around the driven pulley 12, so that the rotation of the crankshaft of the engine can be freely transmitted to the rotating shaft 3 via the endless belt. Moreover, a stator 13 is fixed to a part surrounding the rotor 10 on the inside of the housing 2. In the alternator 1 constructed in this manner, the rotating shaft 3 provided with the rotor 10 is rotated by the rotation of the engine, and electric current is generated in the stator 13 facing this rotor 10.

[0004]

[Problems to be Solved by the Invention]

When the alternator 1 constructed as described above is in use, while the inner rings 6, 6 constituting the rolling bearings 4, 4 rotate, a radial load is continuously applied in the same direction to the inner rings 6, 6 based on

the tension of the endless belt. When such a radial load is applied to the outer rings 8 via the balls 9, 9, and the rigidity of the housing 2 securing the outer rings 8 is low, there is a possibility that the outer rings 8 may elastically deform together with the housing 2. Such elastic deformation of the outer rings 8 is considered to be a cause of damage such as premature flaking of the outer rings 8.

[0005]

That is to say, it is considered that, when the outer rings 8 elastically deform together with the housing 2 based on the radial load, this radial load is applied to the outer ring 8 as an unbalanced load, and the outer rings 8 vibrate more readily. Under such an unbalanced load and vibration, it becomes more difficult to form an oil film of lubricant such as grease or lubricating oil on the rolling contact parts between the inner ring raceway 5 and the outer ring raceway 7 and the rolling contact surface of each ball 9. Furthermore, if the lubricant contains water, or if moisture penetrates from the outside, there is also a possibility that formation of an oil film on the rolling contact parts will become more difficult. When it becomes difficult to form an oil film on the rolling contact parts in this manner, metal-to-metal contact occurs more readily between the inner ring raceway 5 and the outer ring raceway 7, and the rolling contact surface of the balls 9, 9, and there is a possibility of premature flaking of the inner ring raceway 5, the outer ring raceway 7, and the rolling contact surface of the balls 9, 9.

[0006]

Inventions are disclosed to prevent such premature flaking in, for example, Japanese Unexamined Patent Publication No. 2001-221238 wherein the constituents of the material of the outer ring are controlled, and in Japanese Unexamined Patent Publication No. H5-98280 wherein the constituents of the grease are controlled. However, with the rolling bearings incorporated into auxiliary equipment (electrical components) for automobiles, such as alternators and electromagnetic clutches, conditions of use have become more severe with the effects of increased temperature and

speed due to improvements in engine performance associated with recent technical innovations, and increased loads associated with increase in belt tension. Therefore mere control of the components constituting the rolling bearings and the lubricant is no longer sufficient to accommodate these changes in conditions of use, and the possibility of a reduced life due to premature flaking has appeared.

Taking into consideration the above situation, the present invention has been made in order to realize a structure effective for preventing premature flaking.

[0007]

[Means to solve the Problems]

The rolling bearing in accordance with the present invention comprises an inner ring formed with an inner ring raceway on an outer peripheral surface; an outer ring formed with an outer ring raceway on an inner peripheral surface; and a plurality of rolling elements rotatably provided between the inner ring raceway and the outer ring raceway, in the same manner as the heretofore known rolling bearings as has been discussed above.

[0008]

Particularly, in the case of the rolling bearing in accordance with the present invention, when an outer diameter of the outer ring is D, a width of the outer ring in the axial direction is W, a minimum thickness of a part where the outer ring raceway is provided on a middle portion in the axial direction of the outer ring is h, and a diameter of each rolling element is Da, the relationship $1.20 \leqq \{(h^{1.5} \times W) / (Da^{1.1} \times D^{0.5})\} \leqq 2.00$ is satisfied.

[0009]

[Operations]

According to the rolling bearing of the present invention constructed as described above, even if the outer ring is fixed to a low-rigidity housing made of a light metal such as aluminum alloy, sufficient rigidity of the outer ring can be maintained, and premature flaking based on elastic deformation of the outer ring can be prevented, without needlessly increasing the size of the outer ring, and consequently the rolling bearing.

That is to say, if the rigidity of the housing is low, the outer ring elastically deforms together with the housing to an extent which cannot be ignored, and the load zone is reduced. That is to say, the outer ring is elastically deformed such that it is expanded outwards in the radial direction around the part wherein the load is applied, and the expanded part can no longer support the load. Therefore there is a tendency for the load to be concentrated at the part where the load is applied. If the rolling elements enter the part where the load is concentrated in this manner from the non-load zone, a constraining force is applied abruptly to these rolling elements (the extent of constraint increases considerably), and severe slippage occurs readily between the rolling contact surfaces of the rolling elements and the outer ring raceway and the inner ring raceway. The oil film formed on the rolling contact parts between the rolling contact surfaces of the rolling elements and the inner ring raceway and the outer ring raceway then readily breaks down accompanying this slippage, and metal-to-metal contact occurs readily between the rolling contact surfaces of the rolling elements and the inner ring raceway and the outer ring raceway. Moreover, also if the rolling elements spring out from the load zone, since they are suddenly released from a large constraining force, slippage occurs in the same manner, and metal-to-metal contact occurs readily accompanying this slippage. Premature flaking then occurs readily in the rolling contact parts between the rolling contact surfaces of the rolling elements and the inner ring raceway and the outer ring raceway based on this metal-to-metal contact. If the rigidity of the housing is low, the outer ring raceway also readily deforms elastically (such that the peripheral groove forms a wave-shape in the radial direction) based on the load from the rolling elements in (passing through) the load zone. The slippage also occurs readily due to elastic deformation of the raceway face in this manner, and may accelerate premature flaking.

[0010]

Therefore the thickness h and the width W of the outer ring are optimized so that as mentioned above, these are

controlled to $1.20 \leqq \{(h^{1.5} \times W) / (Da^{1.1} \times D^{0.5})\} \leqq 2.00$, and elastic deformation of the outer ring does not occur readily, and premature flaking due to the mechanism described above is thus prevented. If the value calculated in the expression $\{(h^{1.5} \times W) / (Da^{1.1} \times D^{0.5})\}$ (hereafter referred to as 'K') is less than 1.20, the rigidity of the outer ring is too low, and if the outer ring is fixed to a low-rigidity housing made of aluminum alloy or the like, elastic deformation of the outer ring occurs readily and flaking as described above may occur at an early stage. On the other hand, if K exceeds 2.00, the rigidity of the outer ring may be too high, so that when the rolling elements are assembled into the rolling bearing, deformation of the outer ring exceeds the range of elastic deformation, so that plastic deformation occurs and the outer ring is damaged.

[0011]

[Embodiments of the Invention]

FIG. 1 shows one example of an embodiment of the present invention. The rolling bearing 4a of the present example being a deep-groove type ball bearing comprises an inner ring 6 being a rotating ring formed with an inner ring raceway 5 on the outer peripheral face, an outer ring 8 being a fixed ring formed with an outer ring raceway 7 on the inner peripheral face, and a plurality of balls 9 being rolling elements rotatably arranged between the inner ring raceway 5 and the outer ring raceway 7. Furthermore, sealing rings 14 are provided in the openings at both ends of the part where the plurality of balls 9 are provided between the inner peripheral surface of the outer ring 8 and the outer peripheral surface of the inner ring 6.

[0012]

In particular, with the rolling bearing 4a of the present example, if the outer diameter of the outer ring 8 is D, the width in the axial direction of this outer ring 8 is W, the minimum thickness of the part where the outer ring raceway 7 is provided on the middle portion in the axial direction of the outer ring 8 is h, and the diameter of the balls 9 is Da, the respective dimensions are controlled so that the value K calculated by $\{(h^{1.5} \times W) / (Da^{1.1} \times 0.4 \cdot D^{0.5})\}$ satisfies the

relationship $1.20 \leqq K \leqq 2.00$.

[0013]

According to the rolling bearing 4a of the present example constructed as described above, even if the outer ring 8 is fixed to a low-rigidity housing made of light metal such as aluminum alloy, sufficient rigidity of the outer ring 8 can be maintained, and premature flaking based on elastic deformation of the outer ring 8 can be prevented, without needlessly increasing the size of the outer ring 8, and consequently the rolling bearing 4a.

That is to say, research by the inventor of the present invention has shown that, if the rigidity of the housing is low, the outer ring 8 elastically deforms together with the housing to an extent which cannot be ignored, and premature flaking occurs due to such elastic deformation. Specifically, when the rigidity of the housing securing the outer ring 8 is high, if a load is applied to the rolling bearing, a load distribution from each ball 9 becomes as shown by the arrows in FIG. 2. On the other hand, when the rigidity of this housing is low, the load distribution from each ball 9 becomes as shown by the arrows in FIG. 3. As is apparent from FIG. 2 and FIG. 3, when the rigidity of the housing is high, an average load is applied to the outer ring 8 from a large number of balls 9, 9 (a large load zone), however, when the rigidity of the housing is low, the load is applied to the outer ring 8 concentrated from a small number of balls 9, 9 (small load zone). That is to say, the outer ring 8 is elastically deformed such that it is expanded outwards in the radial direction around the part where the load is applied (lowermost point of radial load zone), and since the expanded part can no longer support the load, there is a tendency for the load to be concentrated at the part wherein the load is applied. If the balls 9, 9 enter the part wherein the load is concentrated in this manner from the non-load zone, a constraining force is applied abruptly to these balls 9, 9 (the extent of constraint increases considerably), and severe slippage occurs readily between the rolling contact surfaces of the balls 9, 9 and the outer ring raceway 7 and the inner ring raceway 5.

[0014]

The oil film formed in the rolling contact parts between the rolling contact surfaces of the balls 9, 9 and the inner ring raceway 5 and the outer ring raceway 7 then readily breaks down in association with this slippage, and metal-to-metal contact occurs readily between the rolling contact surfaces of the balls 9, 9 and the inner ring raceway 5 and outer ring raceway 7. Moreover, also if the balls 9, 9 spring out from the load zone, since they are suddenly released from a large constraining force, slippage occurs in the same manner, and metal-to-metal contact occurs readily accompanying this slippage. Premature flaking then occurs readily in the rolling contact parts between the rolling contact surfaces of the balls 9, 9 and the inner ring raceway 5 and the outer ring raceway 7 based on this metal-to-metal contact. If the rigidity of the housing is low, the outer ring raceway 7 readily deforms elastically (such that the peripheral groove forms a wave-shape in the radial direction) based on the load from the balls 9, 9 in (passing through) the load zone. The slippage also occurs readily due to elastic deformation of the raceway surface in this manner, and may accelerate premature flaking. Furthermore, the metal-to-metal contact occurs more readily with high levels of vibration, high temperatures, and increased water in the lubricating oil and water mixed due to condensation and the like.

[0015]

Therefore the thickness h and the width W of the outer ring 8 are optimized so that as mentioned above, the value K calculated by $\{(h^{1.5} \times W) / (Da^{1.1} \times 0.4 \cdot D^{0.5})\}$ is controlled to within a range of $1.20 \leqq K \leqq 2.00$, and elastic deformation of the outer ring 8 does not occur readily, and premature flaking due to the mechanism described above is thus prevented. That is to say, application and release of constraint of the balls 9, 9 is comparatively gradually performed at both ends in the load zone, and the premature flaking is prevented. If K is less than 1.20, the rigidity of the outer ring 8 is too low, and if the outer ring 8 is fixed to a low-rigidity housing made of aluminum alloy or the like, elastic deformation of the outer ring 8 occurs readily and

flaking as described above may occur at an early stage. On the other hand, if K exceeds 2.00, the rigidity of the outer ring 8 may be too high, so that when the balls 9, 9 are assembled into the rolling bearing 4a, deformation of the outer ring 8 exceeds the range of elastic deformation, so that plastic deformation occurs and the outer ring 8 is damaged.

[0016]

Moreover, the inventor of the present invention also focused on the creep of the outer ring 8 rotating in the same direction as the direction of rotation of the inner ring 6 based on the rotating resistance of the rolling bearing 4a. It was then understood that by optimizing the thickness h and width W of the outer ring 8 as described above so that elastic deformation of the outer ring 8 does not occur readily, premature flaking as described above and creep of the outer ring can be prevented. That is to say, it was understood that by ensuring rigidity of the outer ring 8, a localized increase in the surface pressure between the outer ring 8 and the housing can be suppressed, and creep of the outer ring due to this localized increase in the surface pressure can be prevented.

[0017]

[Examples]

Next is a description of an experiment conducted to verify the effects of the present invention. In the experiment, durability of the samples respectively shown in the following Table 1 and Table 2 was measured. In Table 1 and Table 2, samples within the technical scope of the present invention were examples 1 through 6, and samples outside the technical scope of the present invention were comparative examples 1 through 4. Furthermore, respective samples shown in Table 1 below were based on JIS name-number 6204 (inner diameter d = 20mm, outer diameter D = 47mm, width W = 14mm, ball diameter Da = 7.937mm, minimum thickness h of outer ring = 2.781mm) deep-groove type ball bearings of standard class 2 bearing steel (SUJ2), and samples shown in Table 2 were based on JIS name-number 6207 (inner diameter d = 35mm, outer diameter D = 72mm, width W = 17mm, ball diameter Da = 11.112mm, minimum thickness h of outer ring = 3.694mm) deep-groove type

ball bearings of standard class 2 bearing steel (SUJ2), and the value K calculated by $\{(h^{1.5} \cdot W)/(Da^{1.1} \cdot D^{0.5})\}$ was adjusted by respectively varying the outer diameter D of each outer ring.

[0018]

[Table 1]

	Outer diameter of outer ring D [mm]	$K=\{(h^{1.5} \cdot W)/(Da^{1.1} \cdot D^{0.5})\}$	Sample No.	Test time [hr]
Comparative example 1	Φ47	0.97	1 2 3 4 5	265 303 211 335 198
Comparative example 2	Φ47.5	1.10	1 2 3 4 5	358 387 432 500← 455
Example 1	Φ48	1.22	1 2 3 4 5	500← 465 500← 500← 500←
Example 2	Φ48.5	1.36	1 2 3 4 5	500← 500← 500← 500← 500←
Example 3	Φ49	1.51	1 2 3 4 5	500← 500← 500← 500← 500←

[0019]

[Table 2]

	Outer diameter of outer ring D [mm]	$K=\{(h^{1.5}\cdot W)/(Da^{1.1}\cdot D^{0.5})\}$	Sample No.	Test time [hr]
Comparative example 3	Φ72	1.01	1 2 3 4 5	388 452 546 420 553
Comparative example 4	Φ72.5	1.11	1 2 3 4 5	486 580 530 670 710←
Example 4	Φ73	1.21	1 2 3 4 5	710← 710← 710← 682 710←
Example 5	Φ73.5	1.31	1 2 3 4 5	710← 710← 710← 710← 710←
Example 6	Φ74	1.42	1 2 3 4 5	710← 710← 710← 710← 710←

[0020]

Durability tests of the rolling bearings of the respective dimensions noted in Table 1 and Table 2 were then conducted with a target time of 500 hours (Table 1) and 710 hours (Table 2) under the conditions described below, and time until flaking occurred was investigated. The reason for setting the target times as above was so that the L_{10} life (rated fatigue life) under the conditions of the experiment was 494 hours (Table 1) and 705 hours (Table 2). Moreover, in the current experiment, inner ring rotation was with the outer ring fixed to the housing and the inner ring rotated. Furthermore, with the samples in Table 1, sealing rings were provided in the openings at both ends of the part where the

plurality of balls were provided between the inner peripheral surface of the outer ring and the outer peripheral surface of the inner ring, and lubrication was with grease. Moreover, with the samples in Table 2, no sealing rings were provided, and the openings at both ends of the part where the plurality of balls were provided were left open, and forced lubrication was employed by making lubricating oil circulate through this part.

[0021]

Test conditions were as follows.

(1) Table 1 samples

Number of test samples: Five of each sample.

Internal clearance: C3

Radius of curvature of inner ring raceway and outer ring raceway: 52% of ball diameter

Load: P (bearing load)／C (dynamic load rating) = 0.15

Rotational speed of inner ring: $10000 min^{-1}$

Lubricant: EA2 grease, enclosed capacity 35%

Ambient temperature: 100°C

Water content of grease: 1 weight % of grease

[0022]

(2) Table 2 samples

Number of test samples: Five of each sample.

Internal clearance: C3

Radius of curvature of inner ring raceway and outer ring raceway: 52% of ball diameter

Load: P (bearing load)／C (dynamic load rating) = 0.15

Rotational speed of inner ring: $7000 min^{-1}$

Lubricant: ATF fluid {dynamic viscosity at 40°C = $35 mm^2$ per sec = $35 \times 10^{-6} m^2$ per sec (35 cSt), dynamic viscosity at 0°C = $7 mm^2$ per sec = $7 \times 10^{-6} m^2$ per sec (7 cSt)}

Oil temperature: 0°C

Water content of grease: 1 weight % (30cc) in 3 ℓ of lubricating oil

[0023]

The following points were understood from the results of the experiment conducted under the above conditions.

Firstly, in Table 1, in comparative example 1 (D = 47mm, k = 0.97) having the standard outer diameter of outer

ring and being outside the technical scope of the present invention, no sample reached the calculated life (L_{10} life) of 494 hours, and premature flaking occurred. On the other hand, the majority (14 of 15) of samples in examples 1 through 3 within the technical scope of the present invention satisfied the calculated life. Even if the outer diameter D of the outer ring exceeded 49mm, it was found that premature flaking could be prevented. However, if the outer diameter D of the outer ring exceeded 51mm (K = 2.10), that is to say, when K exceeds 2.00, the outer ring plastically deforms when assembling the balls into the rolling bearing, and hence this is not desirable.

[0024]

Furthermore, in Table 2, in the comparative example 3 (D = 72mm, k = 1.01) having the standard outer diameter of outer ring and being outside the technical scope of the present invention, no sample reached the calculated life (L_{10} life) of 705 hours, and premature flaking occurred. On the other hand, the majority (14 of 15) of samples in examples 4 through 6 within the technical scope of the present invention satisfied the calculated life. Even if the outer diameter D of the outer ring exceeded 74mm, it was found that premature flaking could be prevented. However, if the outer diameter D of the outer ring exceeded 77mm (K = 2.11), that is to say, when K exceeds 2.00, the outer ring plastically deforms when assembling the balls into the rolling bearing, and hence this is not desirable.

[0025]

The relationship between the life of the rolling bearing and the K value is shown in FIG. 4. As is apparent from FIG. 4, even when the outer ring is fixed to a low-rigidity housing made of aluminum alloy or the like, the outer ring is not readily elastically deformed and sufficient life can be maintained, by controlling K to 1.20 to 2.00.

[0026]

[Effects of the Invention]

Since the present invention is constructed and operates as described above, even when the outer ring is fixed in a low-rigidity housing made of aluminum alloy or the like,

premature flaking can be prevented, contributing to increased durability of various rotating machinery and equipment incorporating the rolling bearing, without needlessly increasing the size of the outer ring. The invention is particularly suitable for the case of supporting a rotating shaft provided with a pulley or gear such as with an alternator or a transmission, in a housing made of a low-rigidity material such as aluminum alloy as described above, and can contribute to increased durability and reliability of such an alternator or transmission.

[Brief Description of the Drawings]

[FIG. 1] A partial section view showing an example of the embodiment of the present invention.

[FIG. 2] A diagram schematically showing load applied to an outer ring via rolling elements, in the case of a high-rigidity housing.

[FIG. 3] A diagram schematically showing load applied to the outer ring via rolling elements, in the case of a low-rigidity housing.

[FIG. 4] A graph showing the results of an experiment conducted to verify effects.

[FIG. 5] A simplified section view showing an example of a heretofore known alternator.

[Explanation of Symbols]

1	alternator
2	housing
3	rotating shaft
4	rolling bearing
5	inner ring raceway
6	inner ring
7	outer ring raceway
8	outer ring
9	ball
10	rotor
11	commutator
12	driven pulley
13	stator
14	sealing ring

[Name of Document] Abstract

[Abstract]

[Problem] Even when installed a low-rigidity housing made of light metal such as aluminum alloy, premature flaking can be prevented in the rolling contact parts between the rolling contact surfaces of the balls 9 and the inner ring raceway 5 and the outer ring raceway 7.

[SOLUTION] If the outer diameter of the outer ring 8 is D, the width in the axial direction of this outer ring 8 is W, the minimum thickness of the part where the outer ring raceway 7 is provided on the middle portion in the axial direction of the outer ring 8 is h, and the diameter of the balls 9 is Da, the respective dimensions are controlled so that the value K calculated by $\{(h^{1.5} \times W) / (Da^{1.1} \times D^{0.5})\}$ satisfies the relationship $1.20 \leqq K \leqq 2.00$. As a result, premature flaking based on elastic deformation of the outer ring 8 can be prevented by sufficiently maintaining rigidity of the outer ring 8, without needlessly increasing the size of the outer ring 8.

[Selected Figure] Fig. 1.

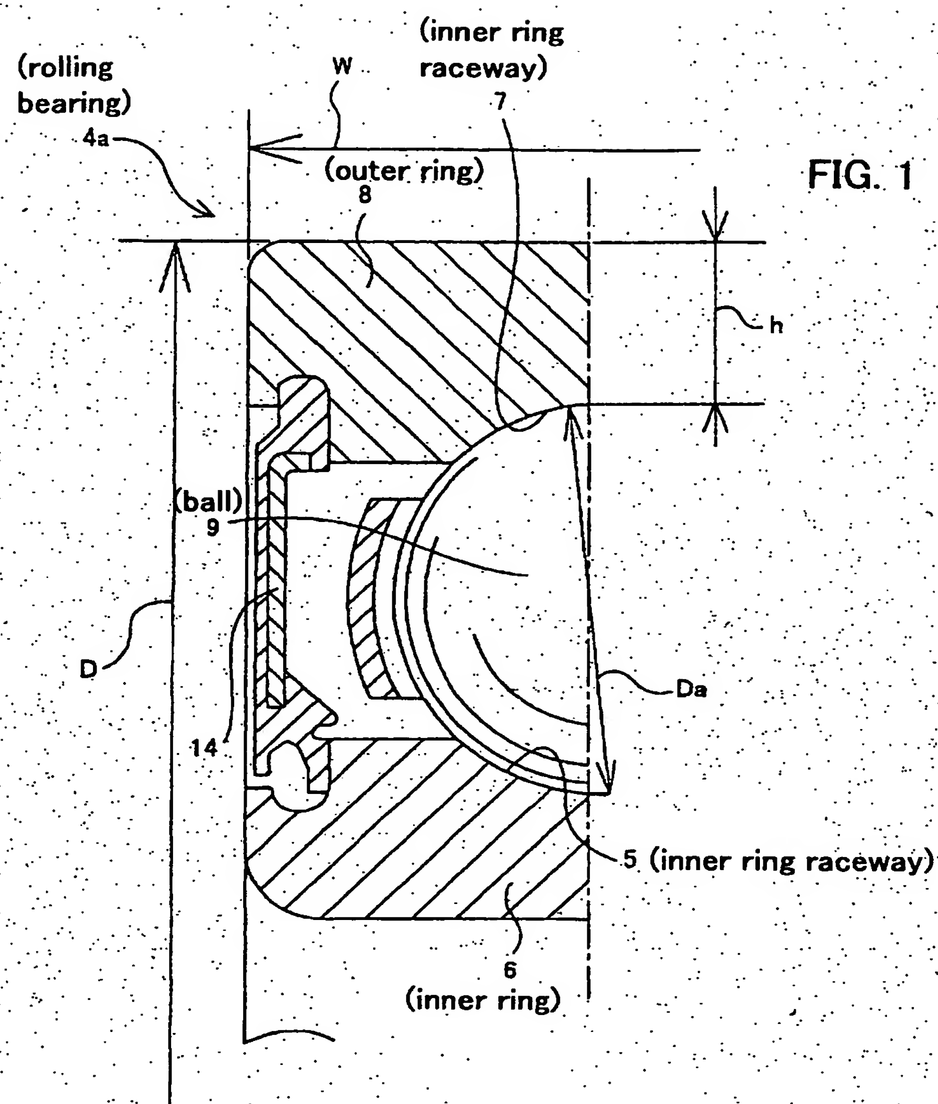
(rolling bearing)
4a
W
(inner ring raceway)
7
(outer ring)
8
h
(ball)
9
D
14
Da
5 (inner ring raceway)
6
(inner ring)

FIG. 1

FIG. 2

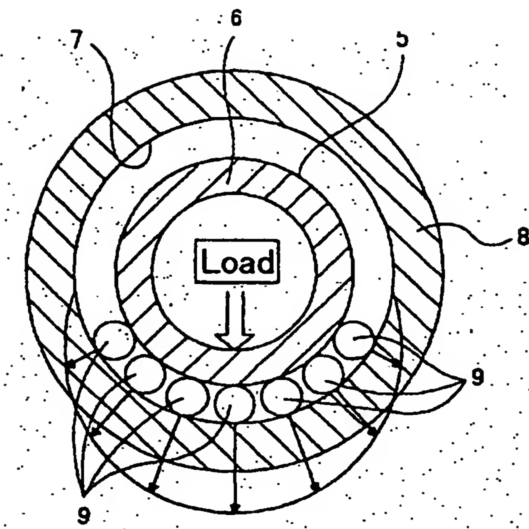

FIG. 3

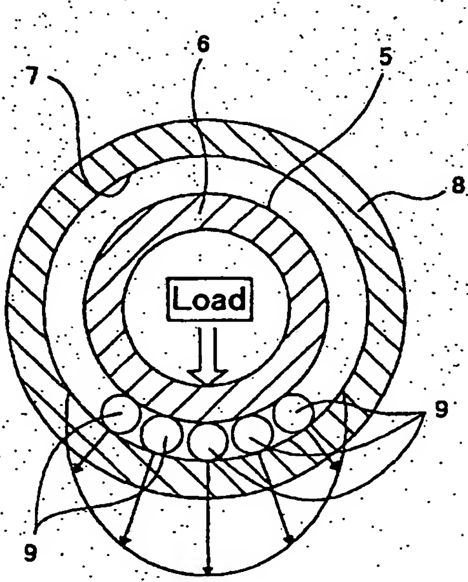

FIG. 4

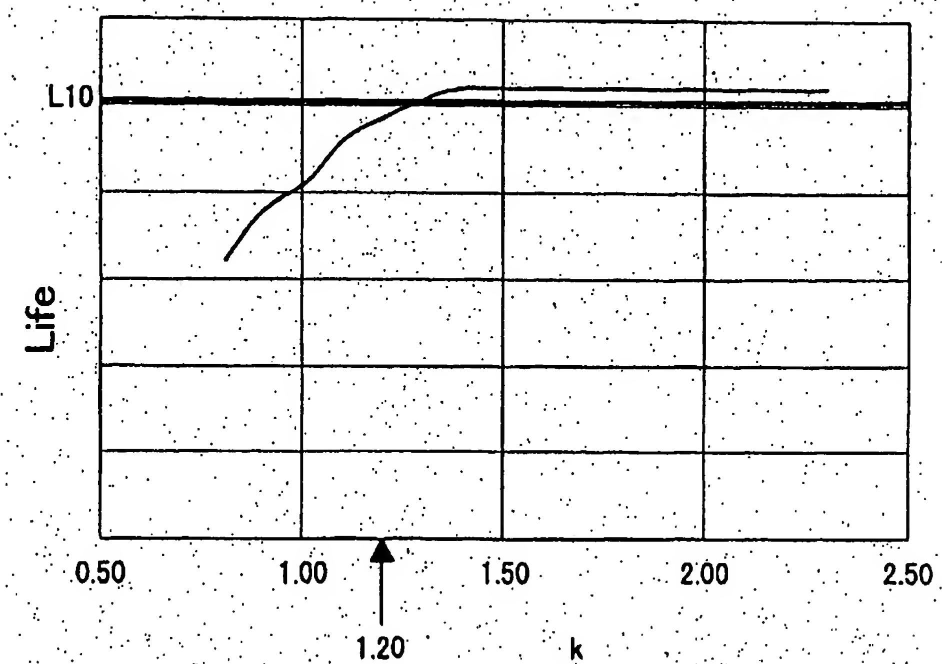

FIG. 5